BODY COMPOSITION MONITORING IN ANOREXIC YOUNG PATIENTS DURING REFEEDING BY FOOT-TO-FOOT IMPEDANCEMETER

M-V. Moreno[1], D. Djeddi[2], M.Y. Jaffrin[1]
[1]UMR-CNRS 6600, University of Technology of Compiègne, COMPIEGNE, France
[2]C.H.U. Nord, pl. Victor Pauchet, 80054 AMIENS
E-mail: morenoma@utc.fr

Abstract-**The goal of this paper is first to investigate different bioimpedance methods for monitoring body composition in anorexic patients. Another goal was to evaluate the feasibility of replacing a Xitron (whole body multifrequency impedancemeter) by a foot-to-foot impedancemeter (FFI) with plantar electrodes, which is cheaper and more convenient to use than medical impedancemeters. Results show that FFI, with some modifications, could replace the Xitron for measuring extracellular, total body water, fat free mass and fat mass but the body cell mass measured by the FFI was significantly different from that of Kotler measured by the Xitron.**
***Keywords* – Body cell mass, denutrition, impedancemetry**

I. INTRODUCTION

Anorexia nervosa (AN) is an eating disorder which induces fat and protein depletion and mainly affects adolescent girls aged from 10 to 18 years. Body composition analysis by bioimpedance is a convenient diagnostic tool [1] as it is non invasive and can be repeated frequently and weight monitoring alone is not sufficient. Foot-to-foot impedancemeter which measures fat free mass (FFM) and fat tissue mass (FM) in addition to weight are particularly attractive because of their low cost and convenience as they use indefinitely reusable plantar electrodes and measurements are taken in up right position. However, in these devices the current only circulates in the legs and lower part of the trunk and the equations giving whole body FFM with such devices have been established with dual absorptiometry (DXA) in healthy adults. Thus their applicability to young anorexic patients with untypical body morphology must be investigated.

II. METHODOLOGY

16 anorexic adolescents (age 10.5-17 years) selected according to the DSM IV criteria, with a body mass index (BMI)=14.4±1.3 kg.m-2, hospitalized for AN at Amiens North Hospital participated in the study together with 20 control subjects of same age group (8-15.5 years) and a BMI=19.8 ± 4.2 kgm^{-2}, after their parents had signed informed consent. Only 9 AN patients underwent a DXA examination and their physical characteristics are summarized in table 1. The protocol has been approved by the Picardie Regional Ethical committee.

TABLE I
Physical characteristics of AN patients having undergone DXA examination

	AN Patients n=9	
	Mean	SD
Age (years)	14.6	1.6
BMI (kg.m-²)	14.4	1.3
Height (cm)	156.2	11.4

Two impedancemeters were used in this study, a multifrequency Xitron 4200® measuring whole body impedance at 50 frequencies between 5 to 1000 kHz with two electrodes on right hand and two on right foot as described in [2], and a TEFAL Bodymaster® FFI with 4 reusable electrodes under heels and toes. This device operates on four 1.5 volt batteries and uses a patented 114 kHz square voltage signal from which low (Ret, measured at top of square wave) and high (Rinft, measured during signal rise) frequencies resistances can be extracted, instead of the resistance at a single frequency (50 kHz) as in other foot-to-foot impedancemeters. It requires entering manually in its software the subject height, age and sex, while his weight is measured by the device to within 0.1 kg.

The FFMt is calculated by the device software from the high frequency resistance, using an undisclosed equation determined by comparison with DXA measurements. FMt is calculated as the difference between weight and FFMt. Our device was modified in order to display the low and high frequency resistances (Ret, Rinft) from which the ECW volumes Vet can be calculated [1] by using

$$V_{et} = K_{et}\left(\frac{H^2 W^{1/2}}{R_{et}}\right)^{2/3} \quad (1)$$

Where Ket is equal to 0.285 for men and to 0.265 for women when patient height H is in cm, weight W in kg, Ret in ohm and Vet in liter.

In addition we have used a new method [3] for calculating the total body water (TBW) volume (Vtn) from R∞, the resistance extrapolated at infinite frequency by the Xitron, taking into account the presence of non-conductive elements, according to the equation, in SI units

$$V_{tn} = \left(\frac{\rho_\infty K_b H^2 W^{1/2}}{R_\infty D_b^{1/2}}\right)^{2/3} \quad (2)$$

Where the body shape factor Kb is taken equal to 4.3 as in the BIS method [9], the body density Db is equal to 1.05 kg/L, and the mean TBW resistivity ρ∞ is taken equal to 104.3 Ωcm for men and 100.5 Ωcm for women. Thus (2) may be rewritten as

$$Vtn = Kx\ (H2W1/2/R\infty)2/3 \quad (3)$$

With Kx =0.576 in men and =0.562 in women when H is in cm, W in kg and R∞ in ohm. A similar equation to (3) was obtained for measuring TBW volume with the TEFAL (Vtt)

$$Vtt = Kt\ (H2W1/2/Rinft)2/3 \quad (4)$$

Where Rinft is the high frequency resistance measured by the TEFAL and coefficients Kt are equal to 0.642 for men and 0.590 for women.

Patients were first weighted on the TEFAL and their weight, FFMt, FMt and Ret were recorded. Then, Xitron measurements were performed when subjects had been supine for 15 minutes, entering the weight measured by the TEFAL in the Xitron software. The Xitron displays Vex (ECW) and Vix (ICW). Then its fat-free-mass (FFMx) is obtained by an equation given in the Xitron user's manual

$$FFMx=1.106\ Vex+1.521Vix \quad (5)$$

Where the coefficients 1.106 and 1.521 represent respectively the densities of extra and intracellular tissues in kg/L.

We also compared body cell mass determined by various bioimpedance methods. Body cell mass from TEFAL (BCMt) was calculated from

$$BCMt= FFMt- BMC-1.106\ Vet \quad (6)$$

Where BMC is the bone mineral content. The body cell mass was also calculated from Xitron data as

$$BCMx= FFMx- BMC-1.106\ Vex \quad (7)$$

Using (6-7) BMC was calculated in patients and controls from a correlation suggested by the Xitron manual using corresponding FFMx for BCMx and FFMt for BCMt.

$$BMC = 0.068\ FFM \quad (8)$$

Finally Kotler's BCMk in kg was calculated using [4]

$$BCMk = 0.0083\ TBK \quad (9)$$

Where the total body potassium concentration is estimated from the reactance X and resistance R at 50 kHz by

$$\text{Men: } TBK = 44.89\ H^{1.6} / Xcp^{-0.5} + 18.52W - 386.66 \quad (10a)$$

$$\text{Women: } TBK = 1.248\ H^{2.07} / Xcp^{-0.36} + 5.79W - 230.51 \quad (10b)$$

Where Xcp is the equivalent reactance given by

$$Xcp = X + R^2/X \quad (11)$$

Data for AN patients and controls and between various methods and the reference one were also compared using paired Student tests.

III. Results

Mean values and standard deviation of fat free mass and body cell mass by the Xitron and the TEFAL are listed in table 2 together with FFMx and FMd measured by DXA. We have also indicated the student test for comparison of BCMx and BCMt with Kotler method BCMk and for comparison of FFM and FM by Xitron and TEFAL with those of DXA.

TABLE II

Comparison of FFM and FM measured by DXA and three impedance methods. Comparison of BCM calculated from impedance by different methods. Student tests are given for TEFAL, Xitron and new method data relatively to the reference method (DXA for FFM and FM, Kotler's method for BCM)

	AN Patients n=9		
	Mean	SD	P t-test
TEFAL Weight (kg)	35,4	6,7	
TEFAL FFM_t (kg)	30,0	4,7	1,41E-04
TEFAL FM_t (kg)	6,5	1,6	2,42E-04
BCM_t (kg)	17,6	3,9	4.2E-9
Xitron FFM_x (kg)	26,5	5,4	2,95E-06
Xitron FM_x (kg)	10,0	2,3	2,64E-06
BCM_x (kg)	14,2	4,2	0.687
BCM_k Kotler (kg)	14,3	2,5	Reference
DXA FFM_d (kg)	33,2	5,0	Reference
DXA FM_d (kg)	3,6	1,9	Reference

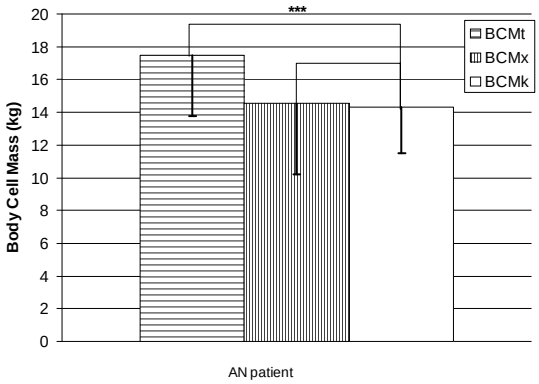

Fig. 1. Histograms of differences in body cell mass (BCM) measured by Tefal, Xitron and Kotler methods (***, p<0.001; **, p<0.01; *, p<0.5).

It can be seen that FFM and FM measured by bioimpedance are significantly different (p<0.001) from those measured by DXA. The BCMx measured by Xitron was not significantly different that of Kotler.

Fig.1 and Table 2 represent BCMt (6), BCMx (7) and BCMk (9-11). BCMt were significantly different from BCMk, taken here as reference. But BCMx was not significantly different from BCMk.

The variation of weight, FFMx, FFMt, FMx, FMt, Vex, Vet in patient A, obtained from Xitron and Tefal data are represented in fig 2 over a period of 26 weeks. We have indicated in this graph the variations of weight, FFMt and FMt given by the TEFAL in g per day and of fluid volumes Vex given by the Xitron in ml per day between weeks 20 and 22. This graph first permits to compare fluid volumes and FFM provided by TEFAL and Xitron devices. Values of Vex and Vet and their variations are very close. The same is true of FFMx and FFMt. Thus the TEFAL, after being modified to provide Ret and Rinf, can monitor fluid volumes with nearly the same accuracy as the Xitron, in addition to FFM and FM. It can be seen also that the weight and FFM of this patient rose slowly to reach a peak at week 24. Her FM fluctuated, but final and initial values were close. While her weight increased by 13.3 g per day, her FFM increased by only 25.3 g per day as her FM increased by the same amount which represented 5 times more than FFM in percentage.

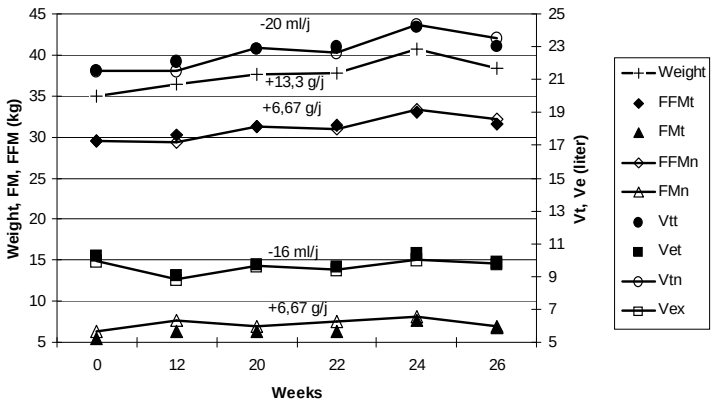

Fig. 2. Monitoring of weight, fat-free mass, fat mass and extracellular water using TEFAL and Xitron impedancemeters in AN patient A. Variations indicated correspond to Weight, FFM_t, FM_t, Vtn and Vex.

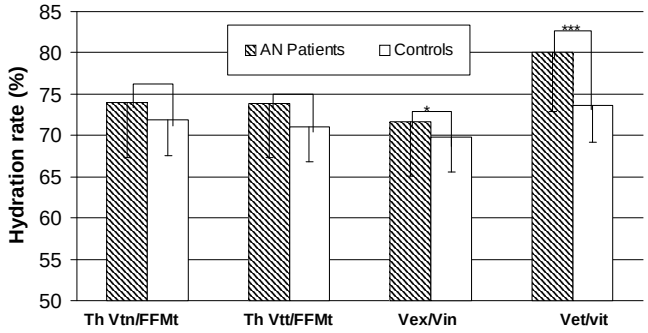

Fig. 3. Histograms of hydration rate Th and ECW/ICW ratio in AN patients (n=39), and controls (n=20) (Vit = Vtt-Vet, Vin = Vtn-Vex) (***, p<0.001; **, p<0.01; *, p<0.5)

Since Vtn was recorded at regular intervals during several weeks in most patients, we have a total of 39 data for the 16 AN patients.

Hydration rates were computed from the ratio of Vtn (our reference method for estimating TBW) FFMt for AN patients and young controls. Results are depicted in Fig.3. The mean hydration rate is slightly higher in AN patients (74%) than in controls (72%), but the difference is not significant.

The 2nd part of the histogram compares the ratio of ECW to ICW volumes in AN patients and young controls. This ratio is significantly higher in AN patients especially when measured by the TEFAL, indicating an excess of ECW.

IV. Discussion

The TEFAL FFI was found to underestimate FFM in AN patients as compared to DXA by 9.6%. This underestimation in AN patients could be due to their particular morphology. Since the current generated by the TEFAL only circulates in the legs and lower part of trunk and the extrapolation to whole body has been calculated for a normal population, skinny legs, which are frequent in AN patients, will induce an underestimation of whole body FFM, if their legs are skinnier than their trunks. However FFM changes measured by the TEFAL during refeeding can be expected to be reliable, at least for moderate weight gains, which will not affect their anatomy very much. A possibility could be to choose as initial FFM that measured by DXA and use the TEFAL for recording FFM changes.

In order to have a frequent monitoring well accepted by a young AN patient, it is important that the examination be fast and with very few constraints. In this respect, FFI have a clear advantage over medical type impedancemeters used in supine position. They measure the patient weight simultaneously with his impedance without the need of pasting electrodes on the hand and foot and the measurements take less than 5 min against about 20 with the Xitron as the patient must wait for fluid equilibrium after lying supine.

Bioimpedance also permits to calculate BCM, which is important, as Earthman et al. [5] have shown that the quality of life and the appetite of denutried patients is improved when their BCM and, more precisely their ratio, BCM/W increases since BCM is the metabolically active body compartment. Kotler's method cannot be used with the TEFAL, which does not provide the resistance and reactance at 50 kHz and the calculation of BCMt by (6) overestimates it in comparison with Kotler's method.

It is interesting to compare our data with those of Mika et al. [6] for young AN patients. Their results showed that, at the beginning of refeeding, the mean TBW to weight ratio of their patients (hydration rate based on weight) was 0.635±0.04 Lkg-1 versus 0.539±0.04 Lkg-1 in control adolescents of same age. After 15 weeks of refeeding, this ratio fell in their patients to 0.583 Lkg-1. During this period, their mean fat mass rose from 5.8 kg to 9.9 kg while their mean FFM increased less from 36.5 to 38.2 kg.. The mean TBW/W of our patients at beginning of therapy was 0.617±0.104 Lkg-1 against 0.539±0.04 in controls. After 20 weeks of refeeding, this ratio fell to 0.586±0.03. During this period their mean FM rose from 5.6±0.7 to 6.3±0.8 kg while their FFM rose very slightly from 26.1±3.8 to 27.4±4.1 kg.. We observed the same normalization of TBW/W as Mika et al., but a smaller increase in FM and FFM, as their refeeding was not yet complete.

V. Conclusion

Our data confirm that foot-to-foot impedancemetry can replace traditional wrist-ankle measurements for evaluating FFM, Ve and FM for AN adolescents with proper modifications.

This study underlines that we have to modify our equation for Body Cell Mass using the TEFAL.

We showed that weight can hide others variations of FM and FFM, for example, which are essential for monitoring effect of refeeding.

References

[1] M.Y. Jaffrin, R. Kieffer, M-V. Moreno, "Evaluation of a foot-to-foot impedancemeter measuring extracellular fluid volume in addition to fat free mass and fat tissue mass", *Nutrition*, 21, 815-824, 2005.

[2] M.Y. Jaffrin, M. Fenech, J-F. de Fremont, M. Tolani, **"**Continuous monitoring of plasma, interstitial and intracellular fluid volumes in dialyzed patients by bio-impedance and hematocrit measurements", *ASAIO J*, 2002, 48:326

[3] M. Fenech, M.Y. Jaffrin, Z. Dabaja, "Validation of total body water measured by multifrequency impedance, *Arch. Physiol. And Bioch*, 2003; 11; 21.

[4] DP Kotler, S Burastero, J Wang, RN Pierso, "Prediction of body cell mass, fat-free mass and total body water with bioelectrical impedance analysis: effects of race, sex and disease", *American Journal of Clinical Nutrition*, 1996; 64: 489S-97S

[5] CP Earthman, PM Reid, IT Harper, E. Ravussin, WH Howell, "Body cell mass repletion and improved quality of life in HIV-infected individuals receiving oxandrolone", *J Parenter Enteral Nutr.*, 2002; 26: 357-65

[6] C. Mika, B. Herpertz-Dalhmann, M. Heer, K. Holtkamp, "Improvement of nutritional status as assessed by multifrequency BIA during 15 weeks of refeeding in adolescents with anorexia nervosa", *J Nutr*, 2004; 134: 3026-30.